

Hunting a New Ocean Tracer

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A useful method to obtain integrated estimates of vertical mixing in the ocean over a long period of time and a large area is the release of a tracer. Recent large-scale tracer release experiments conducted in the Southern Ocean, such as the Diapycnal and Isopycnal Mixing Experiment (DIMES [see Gille *et al.*, 2007]), and in the equatorial Atlantic will rely on a new tracer chemical called trifluoromethyl sulfur pentafluoride (SF_5CF_3), which is likely to become a standard for future experiments. Here we report results from the first injection of pure SF_5CF_3 into the ocean, which was carried out in a deep basin of the Baltic Sea.

Using the Baltic Sea as a natural laboratory for the investigation of physical mixing processes, this pilot study aims at improving our understanding of one of the most puzzling mixing properties in stratified ocean basins: Almost independent of the basin's size, the basin-scale vertical mixing rates exceed the rates inferred from local turbulence measurements in the basin center by approximately 1 order of magnitude [see, e.g., Ledwell and Bratkovich, 1995].

Baltic Tracer Release Experiment

A number of large-scale tracer release experiments, conducted in the past with the extremely nonreactive chemical sulfur hexafluoride, SF_6 , have revealed interesting circulation and mixing patterns that would have been difficult or impossible to obtain with other means [e.g., Ledwell *et al.*, 1998]. Even though SF_6 has proven to be reliably detectable in the ocean down to concentrations of about 10^{-17} moles per liter, the steadily rising atmospheric concentration of SF_6 due to anthropogenic sources is conflicting with its use as a purposefully released tracer, because of both the rising oceanic background concentrations associated with air-sea interchange and the wish of the oceanographic community not to obscure the penetration of this atmospheric signal into the ocean. Because SF_5CF_3 has low background concentrations in both the atmosphere and the oceans, it is seen as a useful alternative for tracer studies [Ho *et al.*, 2008].

We illustrate results from the first successful oceanic injection of pure SF_5CF_3 during the Baltic Tracer Release Experiment (BaTRE), a joint research initiative of the Leibniz Institute for Baltic Sea Research (IOW), in Warnemünde, Germany, and the Leibniz Institute of Marine Sciences (IFM-GEOMAR), in Kiel, Germany. BaTRE also marks the first deployment of a new ocean tracer injection system that was constructed in collaboration with the Woods Hole Oceanographic Institution and is now one of two operational injection systems worldwide.

The injection site chosen for BaTRE was located in the eastern Gotland Basin, the largest deep basin of the Baltic Sea, with a width of about 100 kilometers and a maximum depth of 240 meters (Figure 1a). The physical processes responsible for the basin-scale vertical mixing observed in this region are presently only poorly understood. It is known, however, that the interplay between deep-water renewal by dense bottom gravity currents, intrusions, and deep-water mixing controls the budgets of heat, salt, and matter. As in other ocean basins [Ledwell and Bratkovich, 1995], boundary mixing is believed to play a key role in basin-scale vertical transport processes.

Because these processes are in many respects similar to those controlling the large-scale overturning circulation in the global ocean, our study site may be considered as a natural laboratory where, thanks to considerably reduced scales and simpler logistics, physical processes can be studied with less effort in greater detail and precision. BaTRE aims at improving our understanding of these long-standing research questions with the help of an extensive measuring program, including moored instrumentation, field measurements of hydrographic and mixing parameters, and the release of an inert tracer reported here.

The tracer injection took place on 11 September 2007 during a cruise with R/V *Poseidon* (Figure 1a). A small patch of tracer containing 0.9 kilograms of SF_5CF_3 was injected into a surface of constant density corresponding to a depth of approximately 200 meters at the time of injection. The tracer was "sprayed" into the water column with a system similar to that described by Ledwell *et al.* [1998]; however, to ensure the rapid dissolution of the new, less soluble tracer, the diameter of the orifices was reduced.

Only 12 days after the injection, we used a new technique to relocate the small tracer patch, now considerably distorted because of the current field acting on it. Behind the ship, we towed a pump-conductivity/temperature/depth (P-CTD) system [Strady *et al.*, 2008], consisting of temperature and salinity sensors, and a pump connected to the ship's laboratory via a multifunctional cable. This cable included a nylon hose, which allowed us to analyze hydrographic parameters and a continuous flow of water samples, taken around the injection depth, with our onboard gas chromatograph (GC) systems. The results of the tracer search (Figures 1a and 1b) indicated that the tracer was successfully injected at the desired density level and within a very narrow depth range,

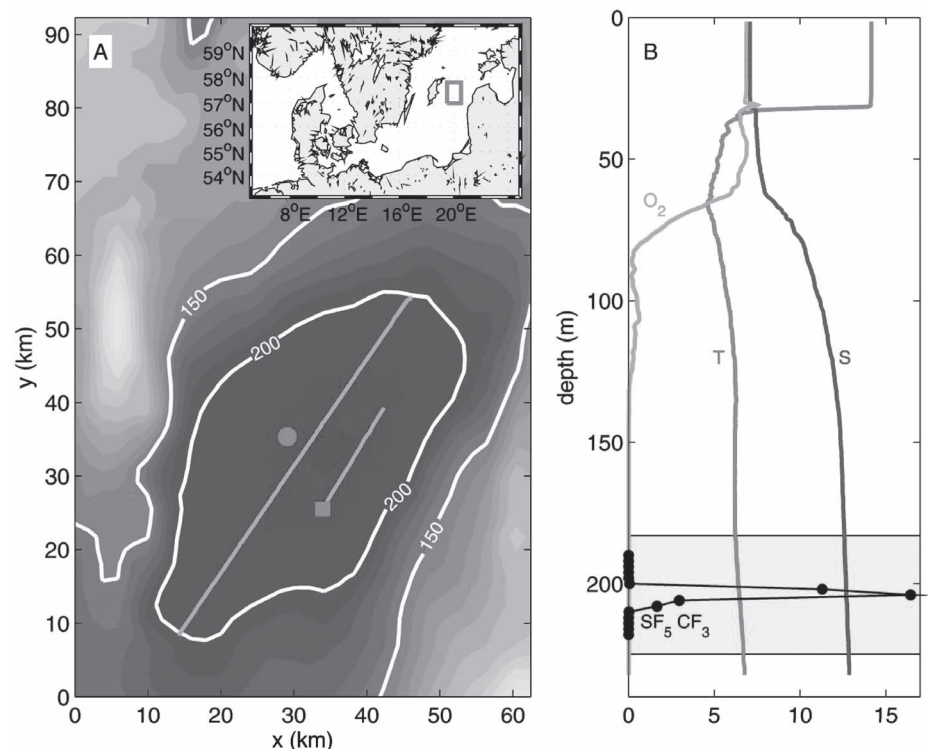


Fig 1. Results of the Baltic Tracer Release Experiment (BaTRE), 12 days after tracer injection. (a) Geographical location of the study area (red rectangle in the inset map), local topography in meters (white contour lines), and ship tracks during tracer search (green lines). The red circle marks the injection site, and the red square marks the location where the tracer was first found 12 days after the injection. (b) Profiles of the temperature (T, in °C), oxygen (O_2 , in milliliters per liter of water), salinity (S, in grams per kilogram), and tracer distribution (the curve with circles within the yellow band, measured as tracer units in 10^{-11} moles per liter of water), all displayed on a common scale along the horizontal axis. Vertical axis is depth. Original color image appears at the back of this volume.

with vertical spreading strongly suppressed due to the stable stratification.

Following the initial survey reported here, additional cruises have been carried out during BaTRE; data are currently being analyzed and compared with data from local hydrographic and turbulence measurements. Research cruises are planned at least until spring 2009 so that scientists may estimate the long-term evolution of the tracer distribution.

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FORUM

Global Environmental Solutions Require Global Funding

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As members of the next generation of environmental scientists, we are committed to conducting solutions-oriented research on global environmental problems. In addition to the highly visible problem of climate change, we face global environmental threats such as biodiversity loss, worsening air quality, and limited food security and water availability. These threats do not stop at national borders. Research in these areas requires global coordination and collaboration, and it would be best served by an equally global funding infrastructure.

The United Nations Framework Convention on Climate Change Conference of the Parties will convene in 2009 in Copenhagen, Denmark, to negotiate post-Kyoto Protocol climate policy. One criterion for the success of these negotiations is their basis in the best available scientific understanding of the climate system at local, regional, and global scales. While the organizational infrastructure for global research coordination exists, funding is managed by national and regional agencies individually, with increasing emphasis on local concerns.

Susan Solomon, a lead author of the 2007 Intergovernmental Panel on Climate Change report, concluded in a 14 March 2008 editorial in *Science* that “the planning and coordination of international research are best

carried out by organizations such as the World Climate Research Programme, the International Geosphere-Biosphere Programme, and the International Human Dimensions Programme.” We advocate a financial support structure organized along similar lines. The International Group of Funding Agencies (IGFA), which exists to coordinate global research efforts, serves as a forum in which national agencies that fund global change research can identify areas of mutual interest, though it does not administer a common fund. IGFA’s organizational infrastructure could be used as a framework for development of coordinated funding.

We suggest the scientific funding agencies around the world create and contribute to a common fund to support global environmental change research. This common fund would allow the most efficient use of resources available. Currently, our success at improving understanding of the global environment is not limited so much by the total amount of funding as by the lack of a global funding structure. One problem that can result from the lack of such a global structure is that large-scale international research programs requiring many partners can be jeopardized if a few of the participating scientists are not supported by their national agencies. A side benefit of such global financial coordination could be to streamline the transition of research results into international policy-relevant informa-

tion, by including in the selection criteria for proposals a requirement that projects focus on truly global aspects of environmental change. Access to the funding would proceed via peer-reviewed competitive research proposals similar to those currently used at the national level in a number of countries, with an international review panel and clear evaluation criteria.

Such interagency collaboration to support science has precedents, at least on the national and regional scales. In the United States, for example, several U.S. federal agencies with different mandates contribute to a common fund under the Climate Change Science Program, which supports national and international research. International examples include the Framework Programme of the European Commission, the Asia-Pacific Network for Global Change Research, and the Inter-American Institute for Global Change Research. We believe that our efforts to produce science in support of climate solutions would benefit from the application of similar international collaboration on worldwide research funding.

We look forward to serving society in the search for solutions to global environmental problems, supported by a truly global funding infrastructure.

This article was written by 26 early career atmospheric scientists who attended the U.S./Nordic workshop, Biogenic Secondary Organic Aerosols: Observations to Global Modeling, in Tovetorp, Sweden, on 11–15 August 2008 (see Meeting Report, this issue of Eos, p. 421). The full list of authors of this article can be found in the electronic supplement to this Eos issue (http://www.agu.org/eos_elec/).

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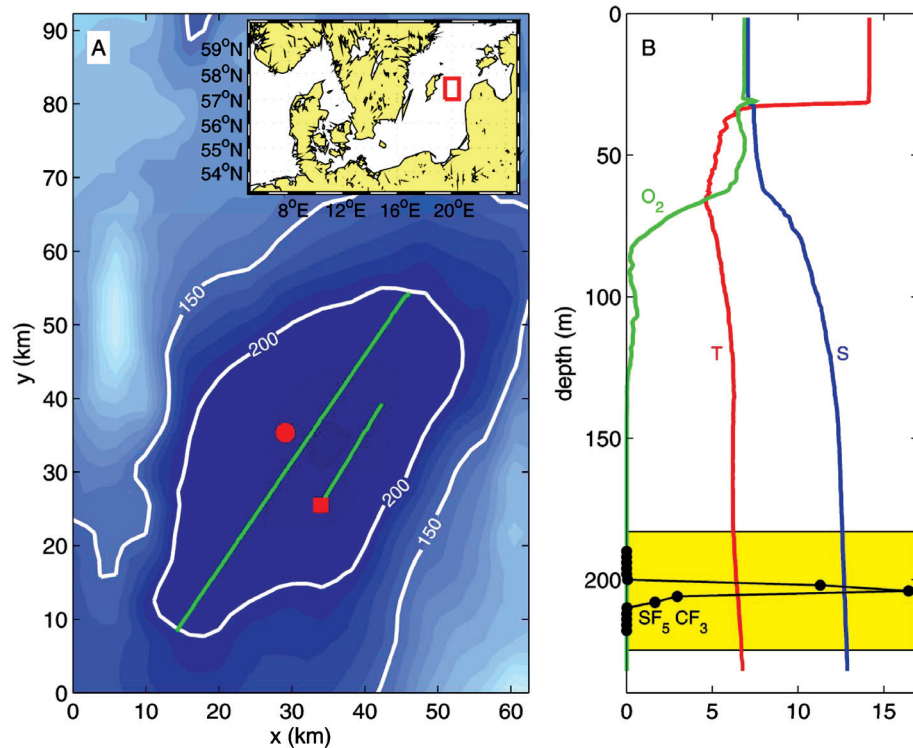
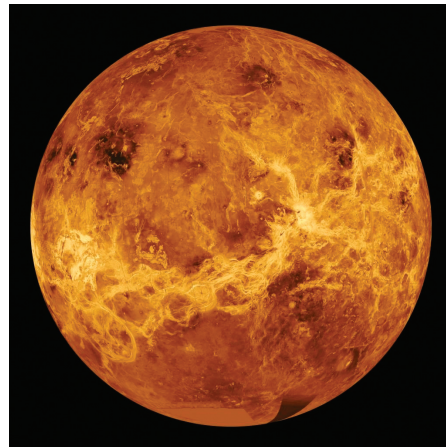


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Using imaging radar, NASA's Venus-orbiting Magellan spacecraft produced high-resolution images of the planet's surface, including this one, in the early 1990s. Photo credit: Magellan Project, Jet Propulsion Laboratory, NASA

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